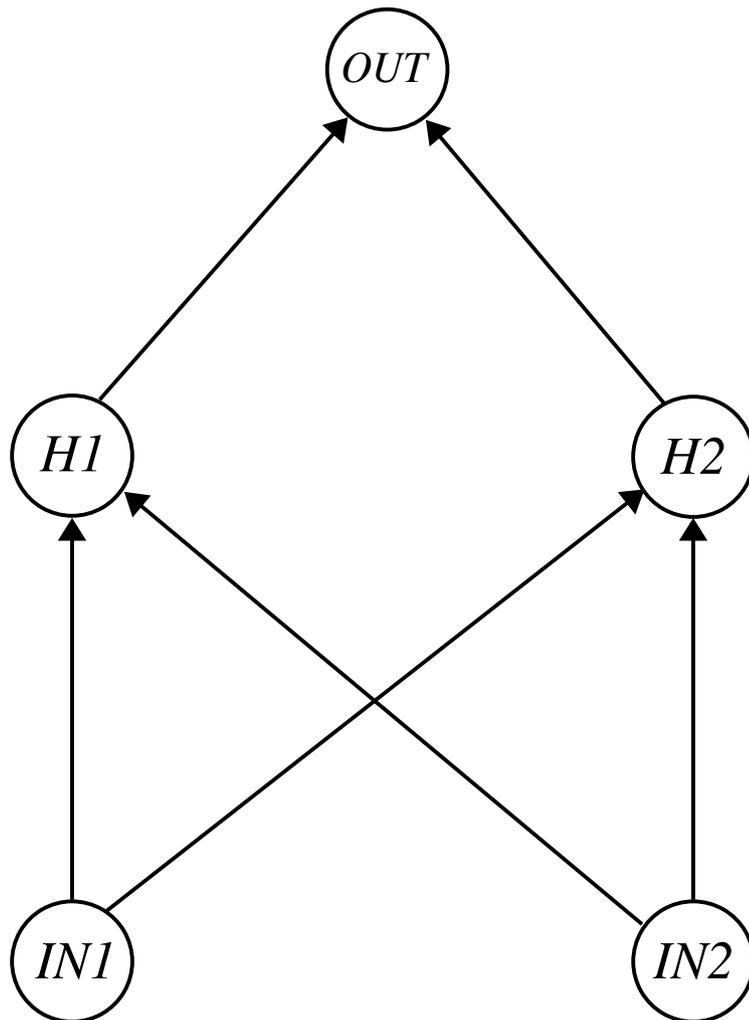
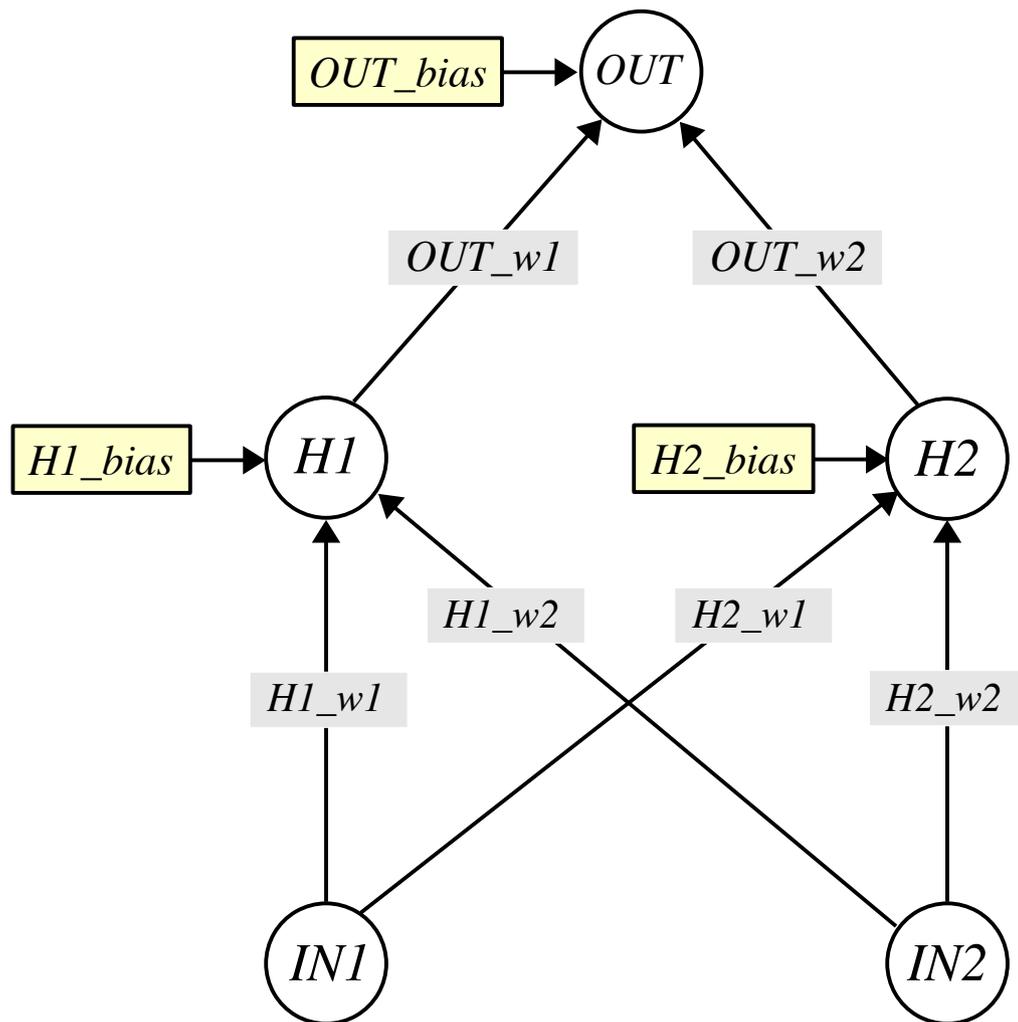


Backpropagation: 2-2-1 Network

Backpropagation: 2-2-1 Network

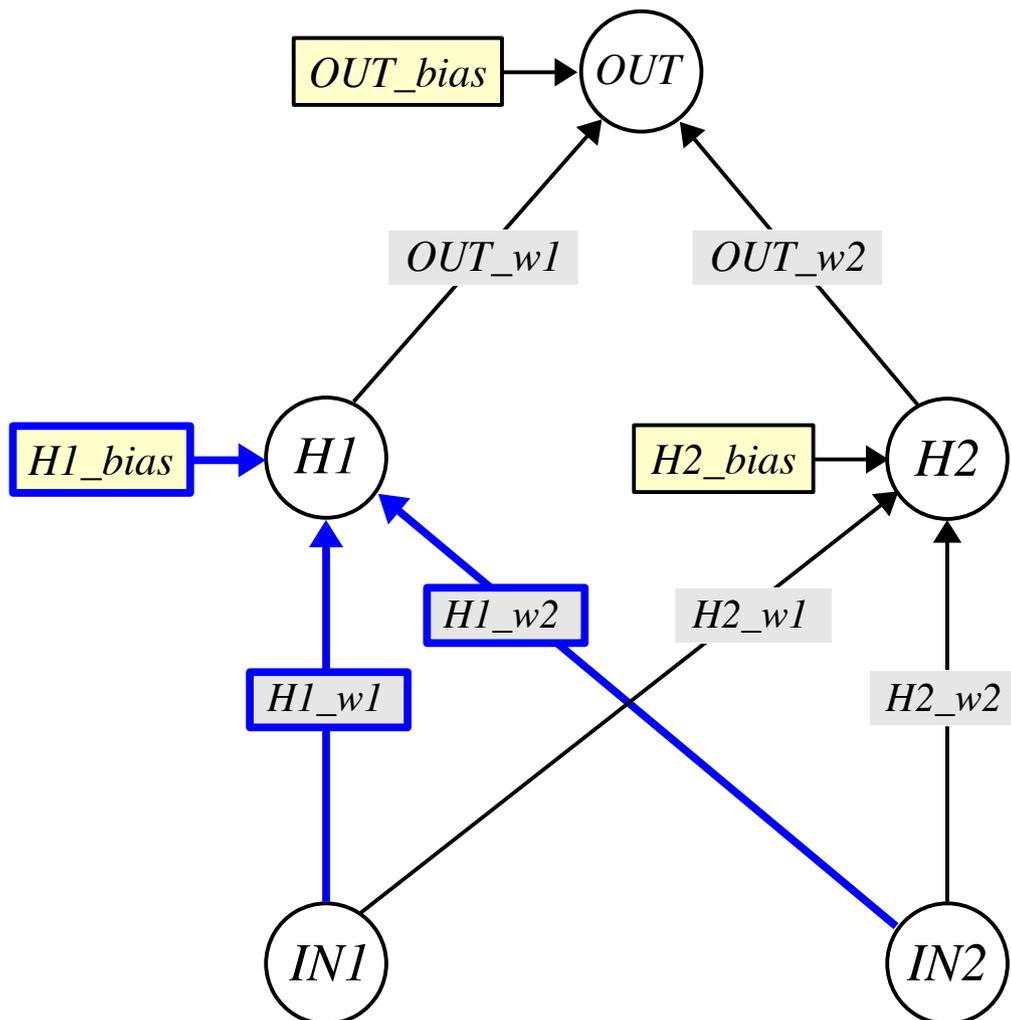


Backpropagation: 2-2-1 Network

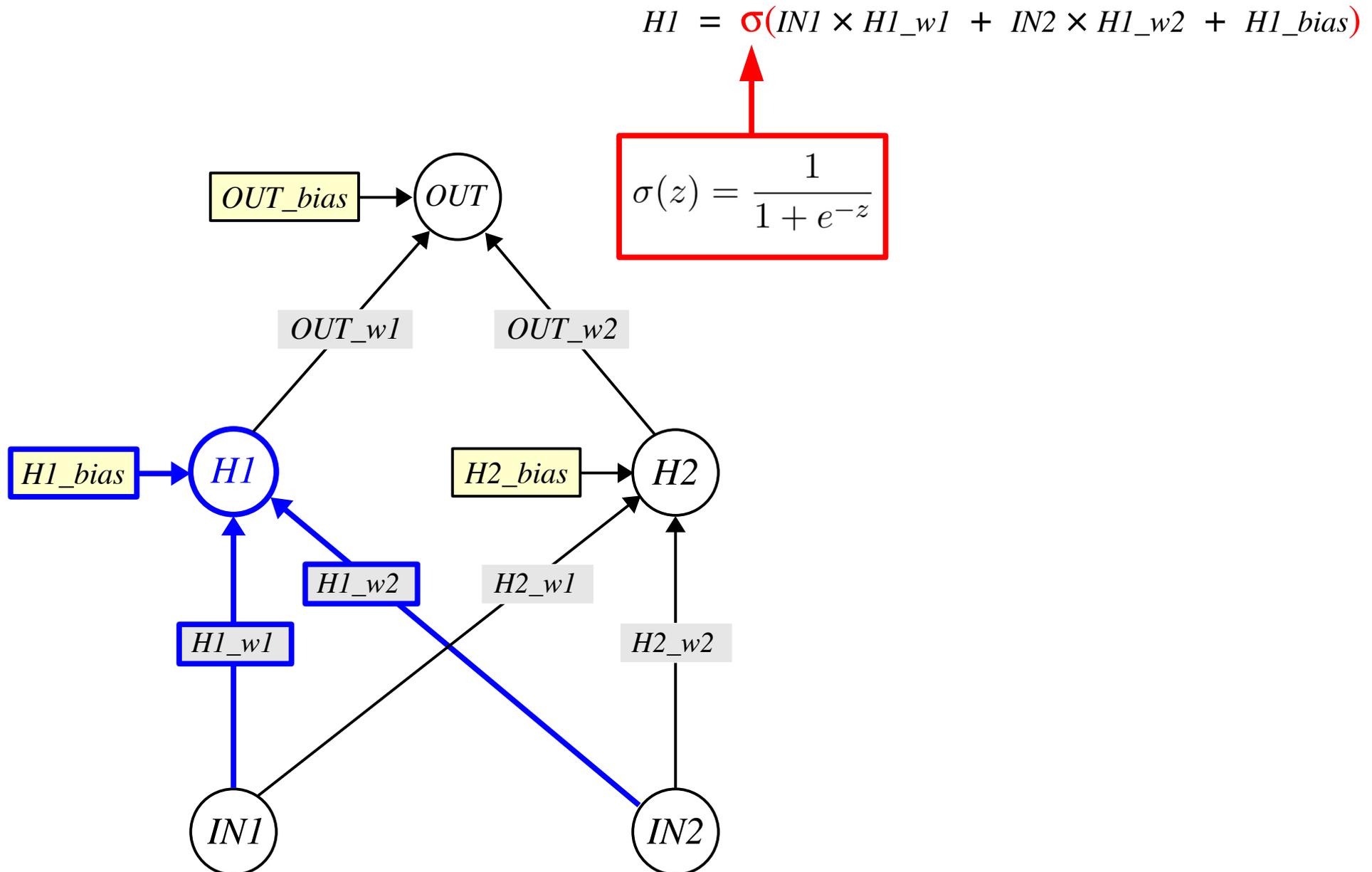


Backpropagation: 2-2-1 Network

$$IN1 \times H1_w1 + IN2 \times H1_w2 + H1_bias$$



Backpropagation: 2-2-1 Network

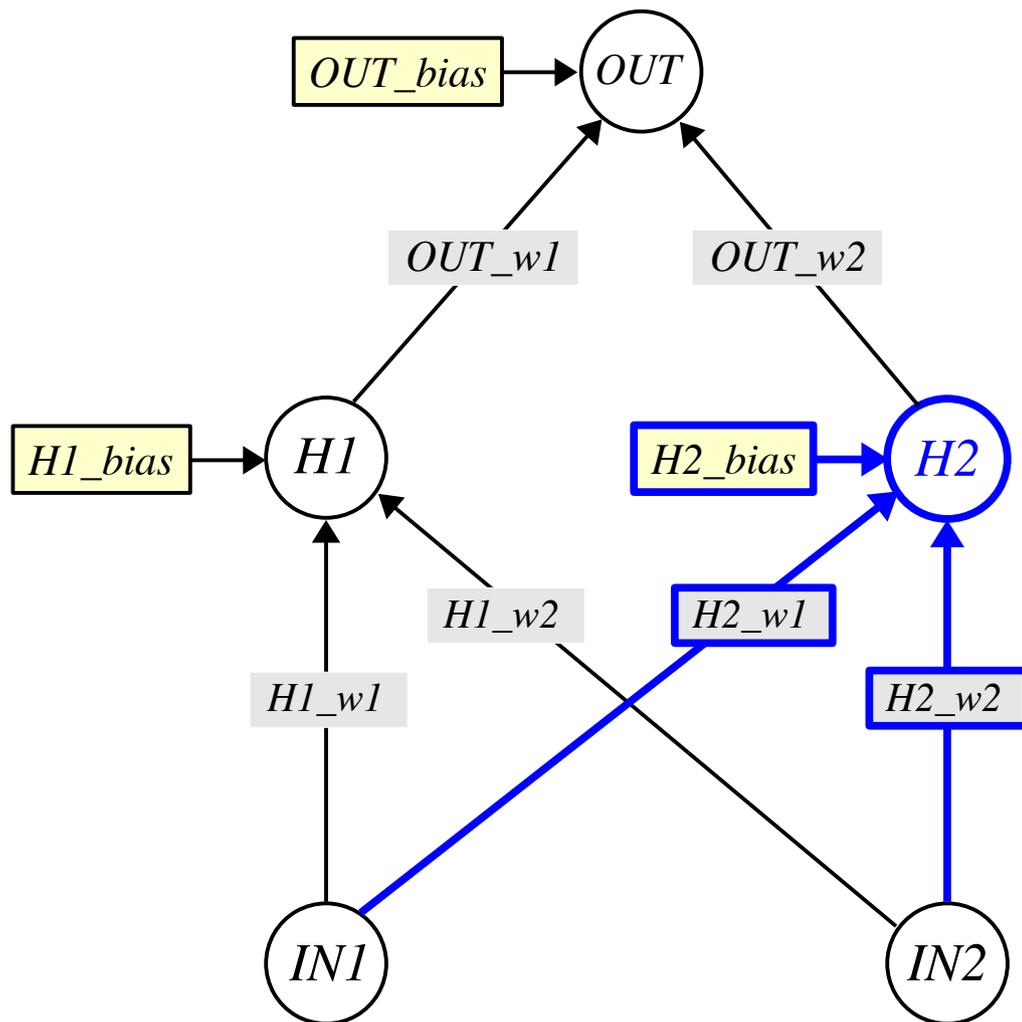


Backpropagation: 2-2-1 Network

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

$$H1 = \sigma(IN1 \times H1_w1 + IN2 \times H1_w2 + H1_bias)$$

$$H2 = \sigma(IN1 \times H2_w1 + IN2 \times H2_w2 + H2_bias)$$



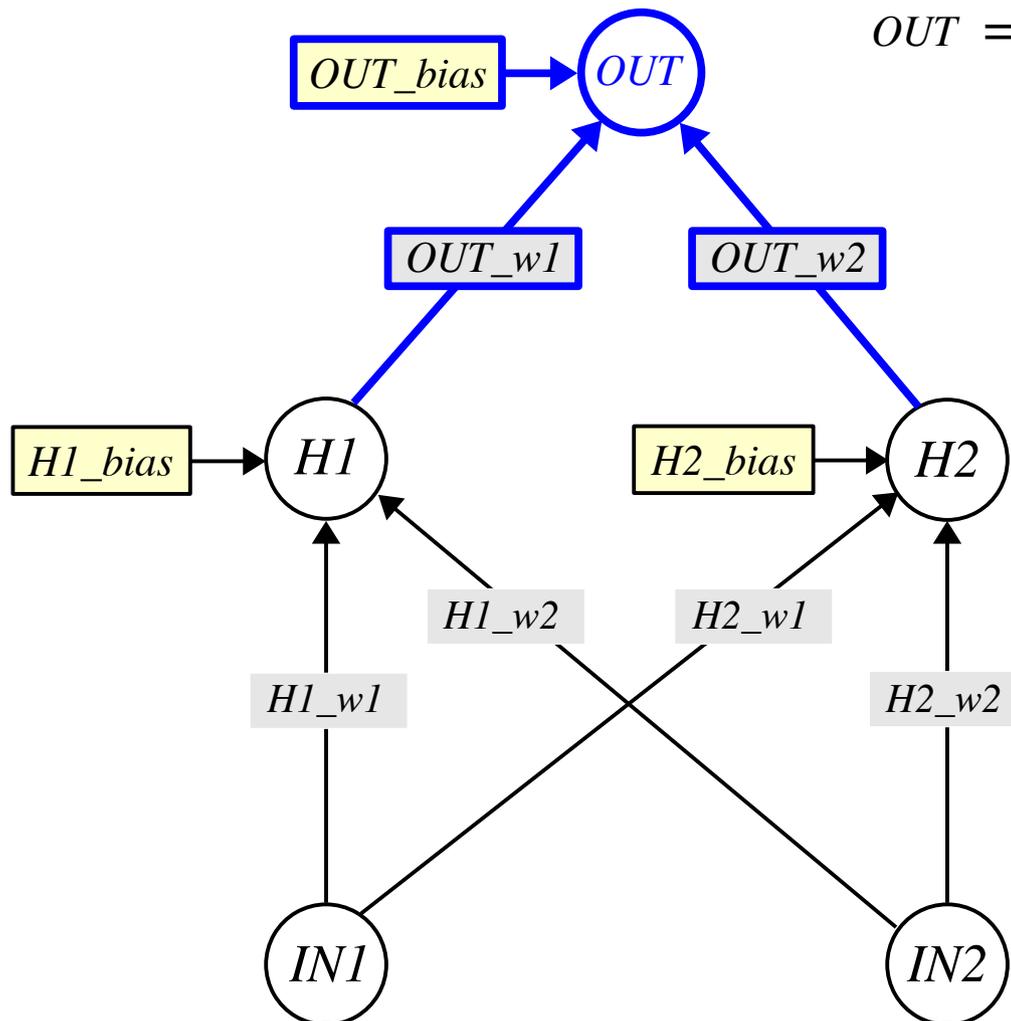
Backpropagation: 2-2-1 Network

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

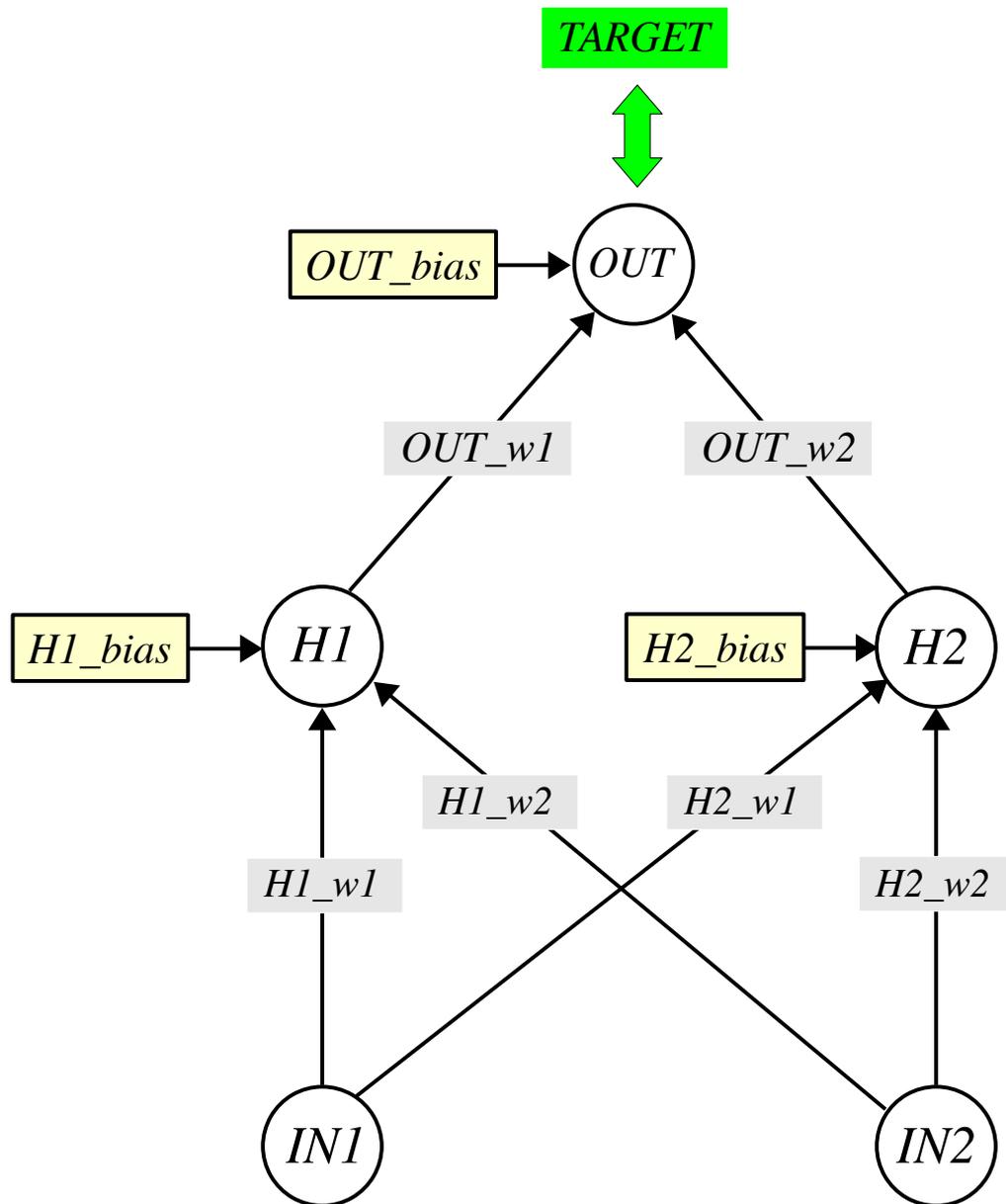
$$H1 = \sigma(IN1 \times H1_w1 + IN2 \times H1_w2 + H1_bias)$$

$$H2 = \sigma(IN1 \times H2_w1 + IN2 \times H2_w2 + H2_bias)$$

$$OUT = \sigma(H1 \times OUT_w1 + H2 \times OUT_w2 + OUT_bias)$$

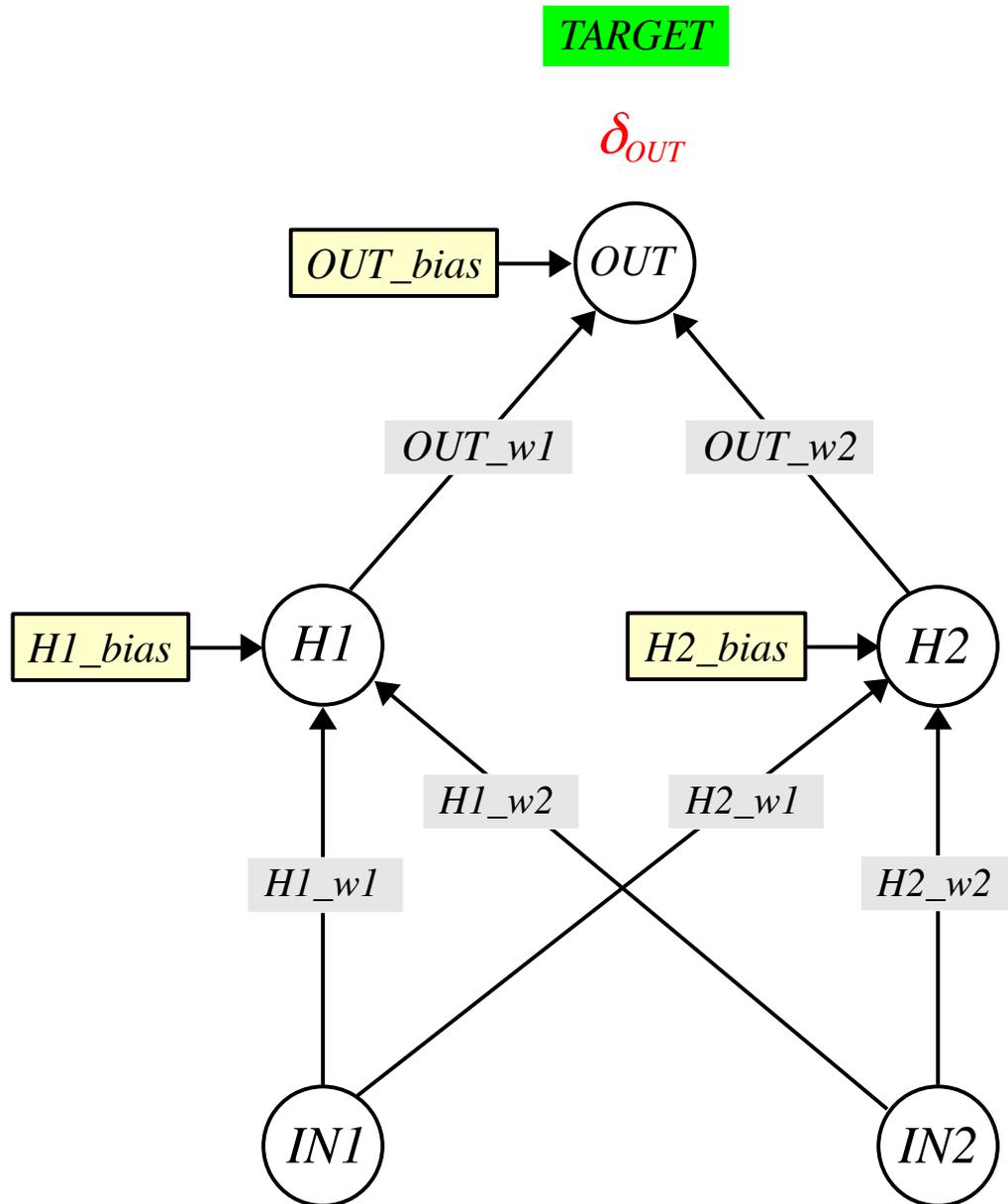


Backpropagation: 2-2-1 Network



Backpropagation: 2-2-1 Network

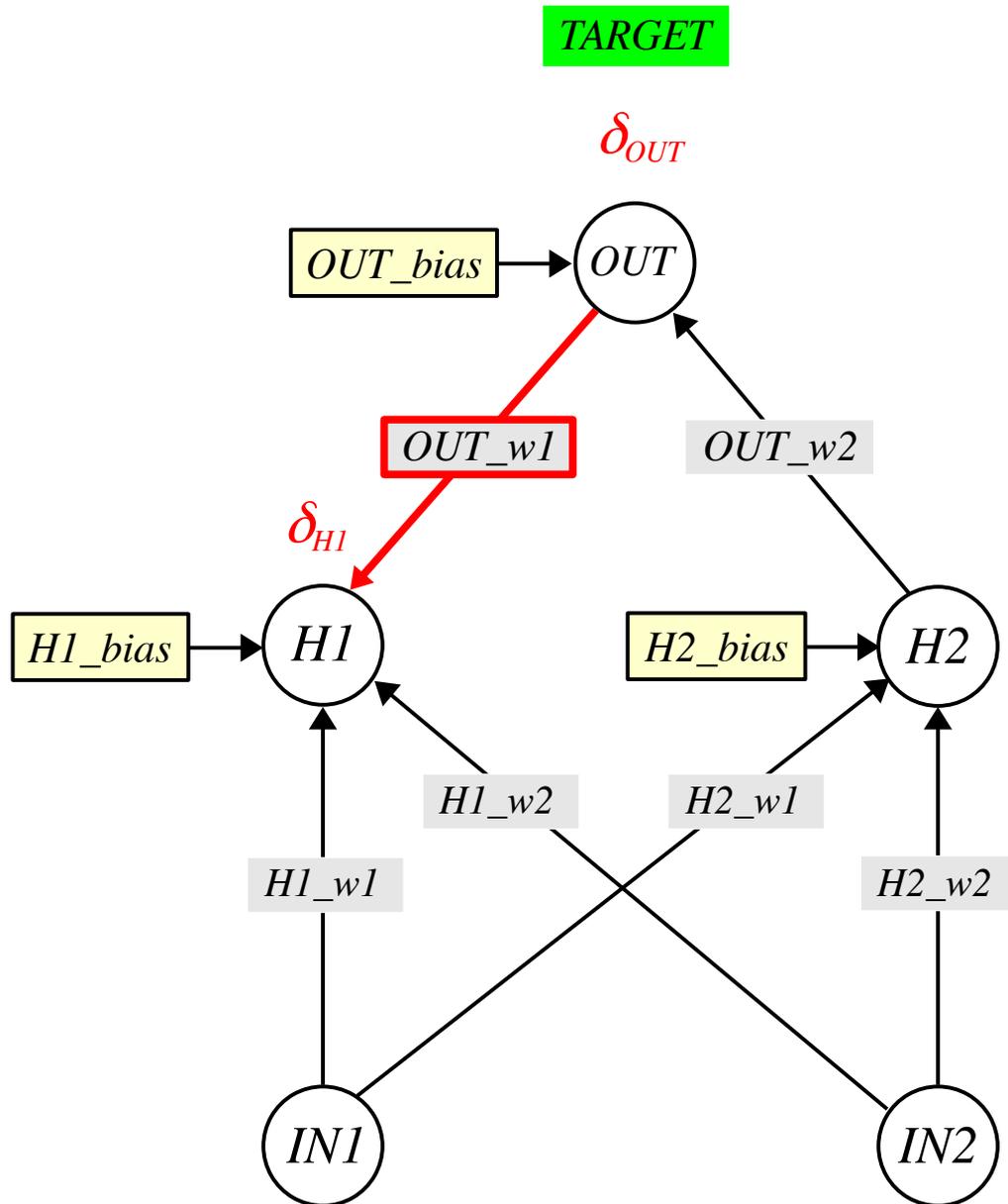
$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$



Backpropagation: 2-2-1 Network

$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

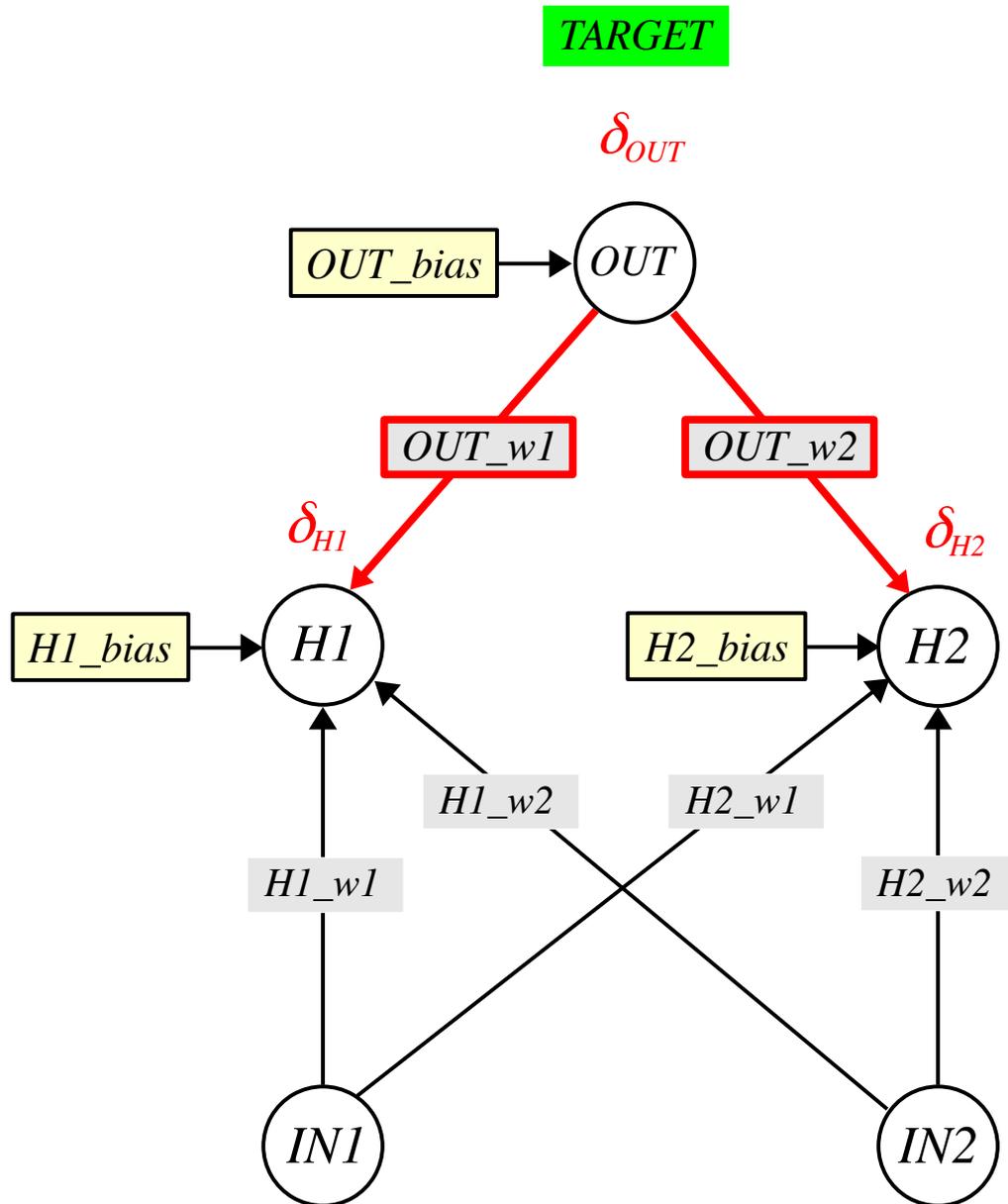


Backpropagation: 2-2-1 Network

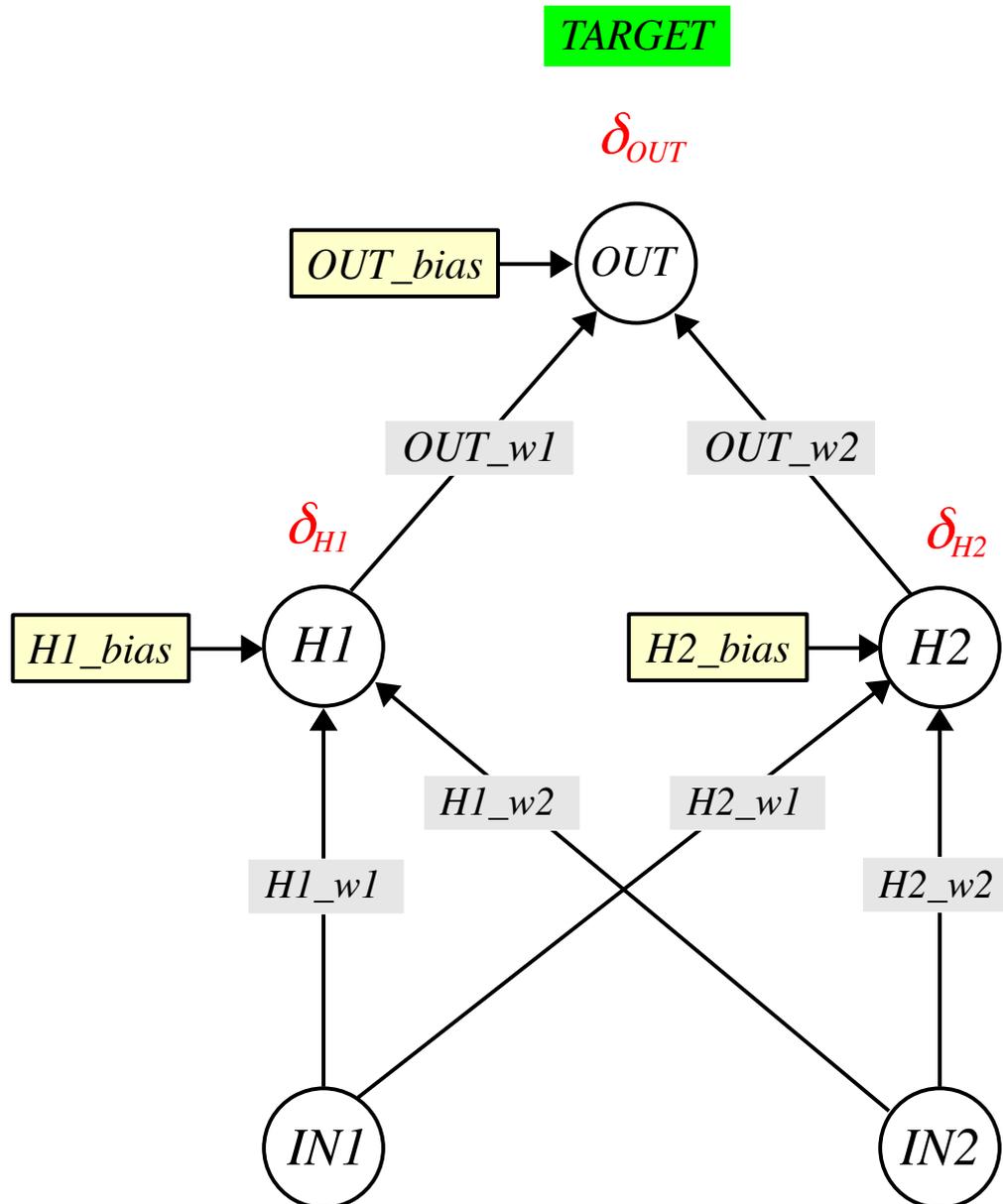
$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_w2) \times H2 \times (1 - H2)$$



Backpropagation: 2-2-1 Network



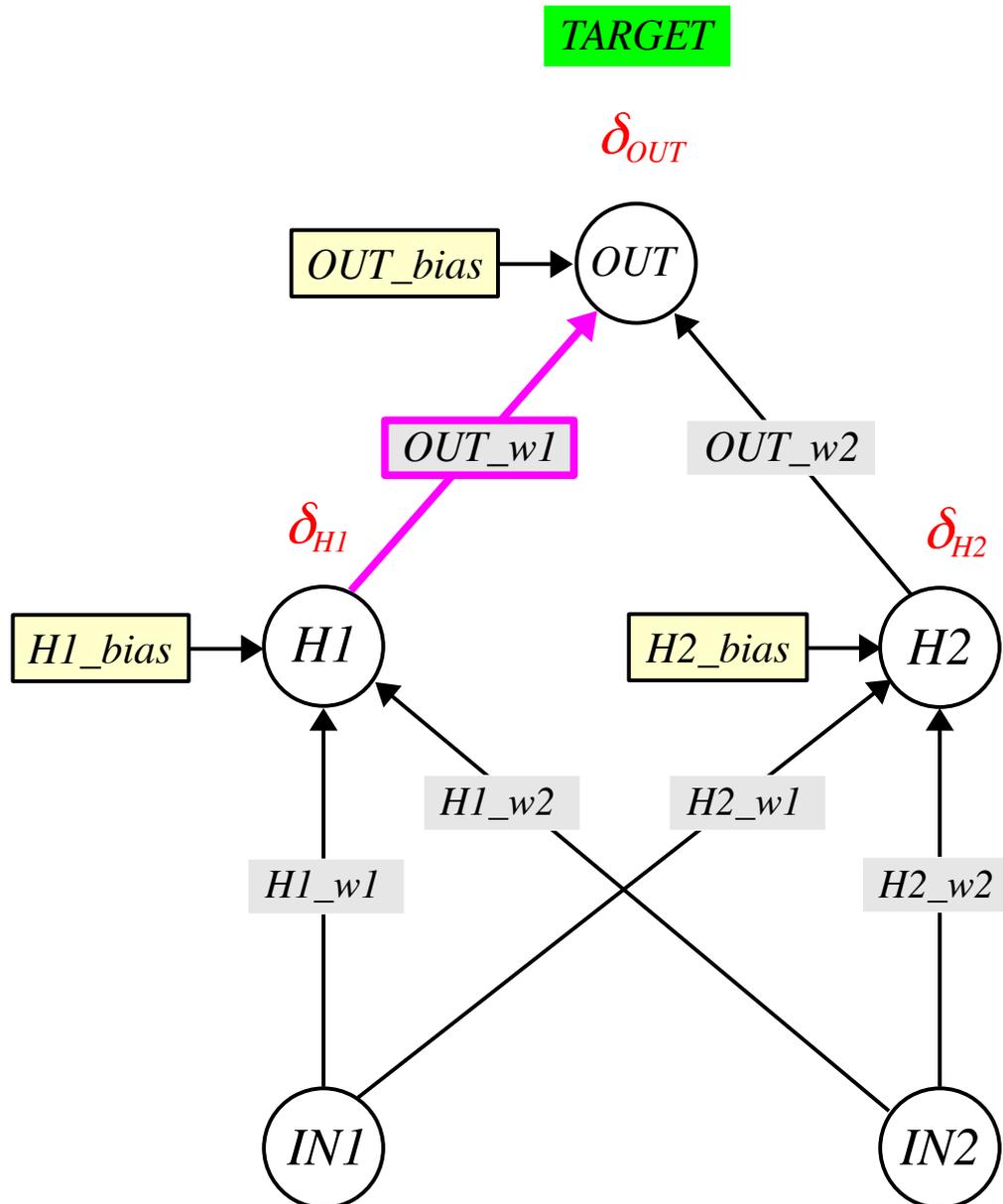
$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_w2) \times H2 \times (1 - H2)$$

Now we are ready to update the weights and biases

Backpropagation: 2-2-1 Network



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_w2) \times H2 \times (1 - H2)$$

$$\Delta OUT_w1 = -\eta \times \delta_{OUT} \times H1$$

Learning rate
 $0 < \eta < 1$

Amount to **change** OUT_w1

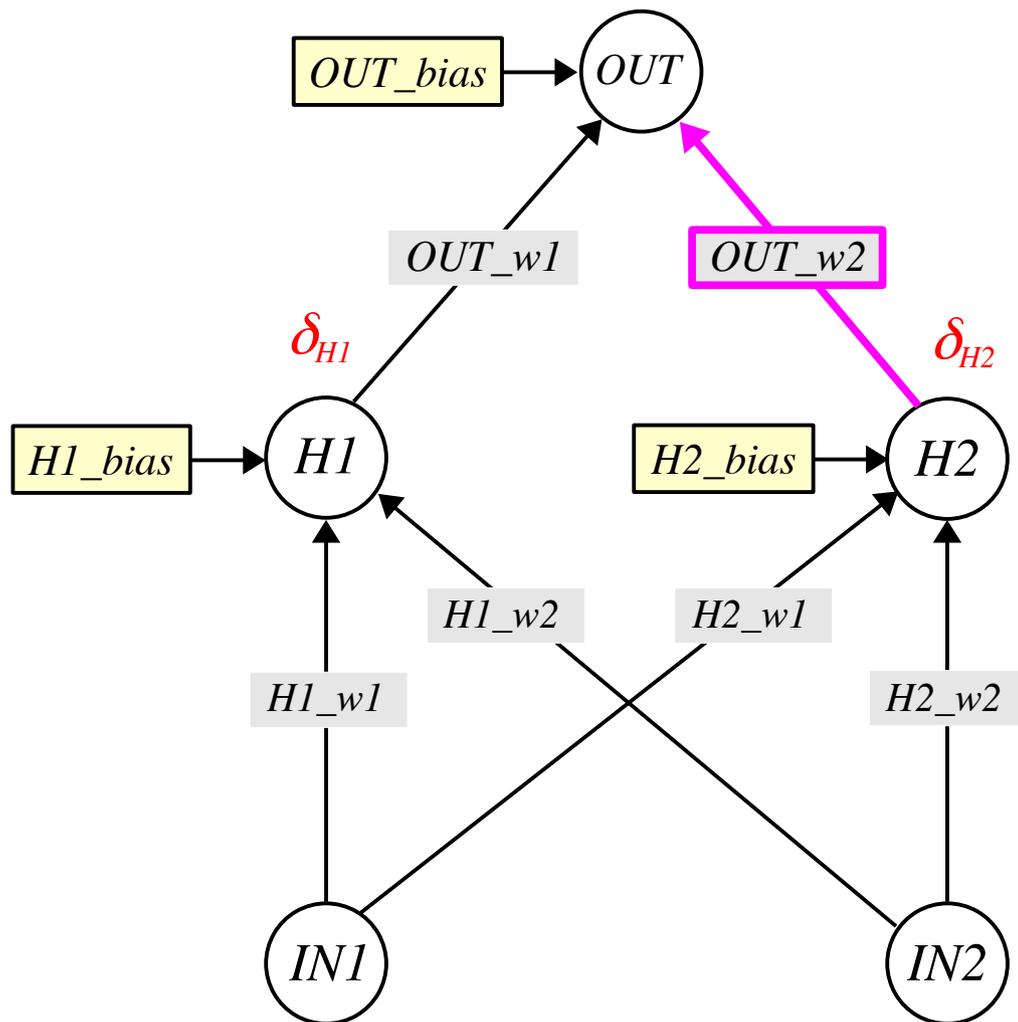
$$OUT_w1 = OUT_w1 + \Delta OUT_w1$$

Backpropagation: 2-2-1 Network

Learning rate
 $0 < \eta < 1$

TARGET

δ_{OUT}



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_{w1}) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_{w2}) \times H2 \times (1 - H2)$$

$$\Delta OUT_{w1} = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_{w2} = -\eta \times \delta_{OUT} \times H2$$

Backpropagation: 2-2-1 Network

Learning rate
 $0 < \eta < 1$

TARGET

δ_{OUT}

OUT_bias



OUT_w1

OUT_w2

δ_{H1}

δ_{H2}

H1_bias



H2_bias



H1_w2

H2_w1

H1_w1

H2_w2



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_{w1}) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_{w2}) \times H2 \times (1 - H2)$$

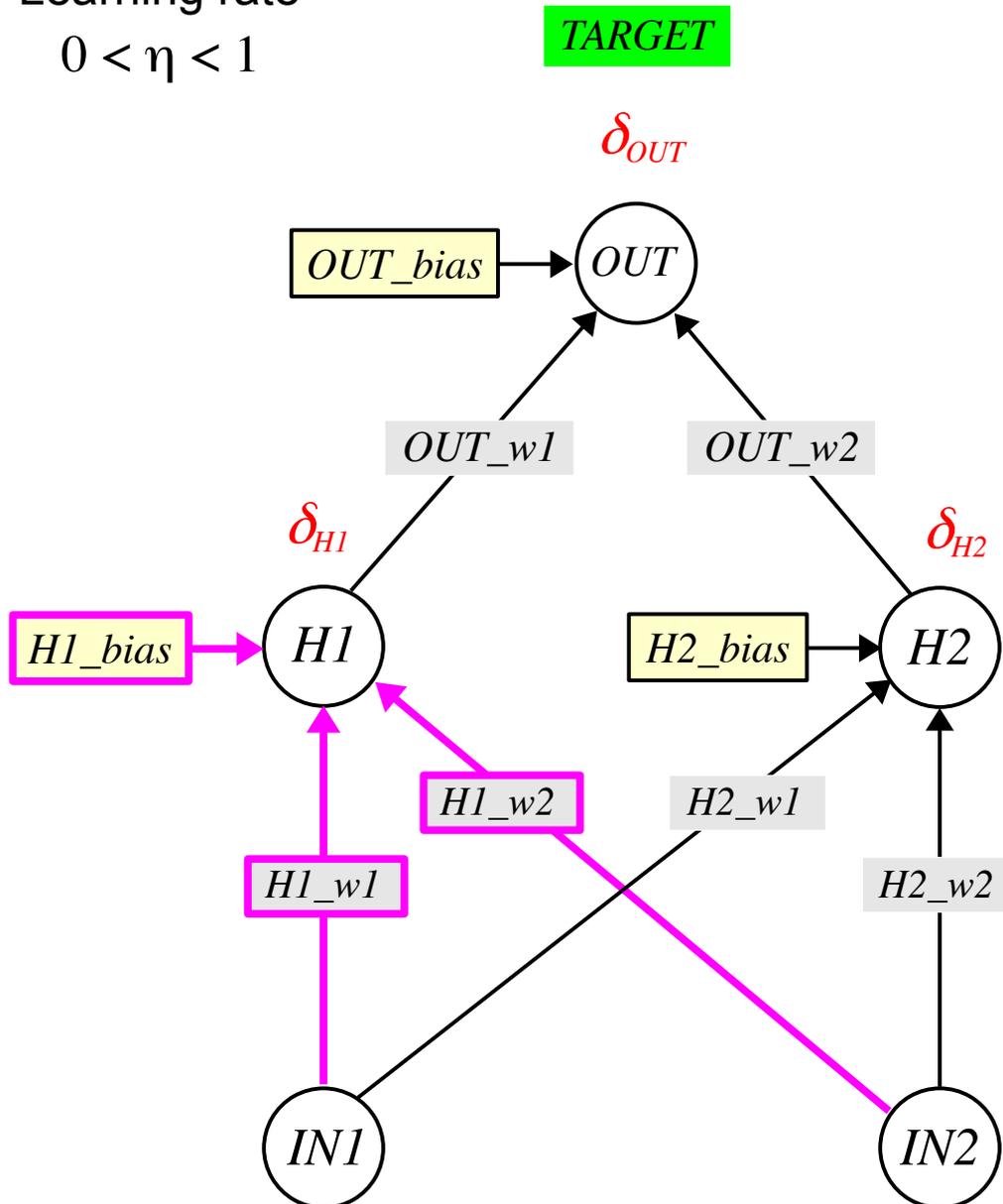
$$\Delta OUT_{w1} = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_{w2} = -\eta \times \delta_{OUT} \times H2$$

$$\Delta OUT_{bias} = -\eta \times \delta_{OUT}$$

Backpropagation: 2-2-1 Network

Learning rate
 $0 < \eta < 1$



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_w2) \times H2 \times (1 - H2)$$

$$\Delta OUT_w1 = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_w2 = -\eta \times \delta_{OUT} \times H2$$

$$\Delta OUT_bias = -\eta \times \delta_{OUT}$$

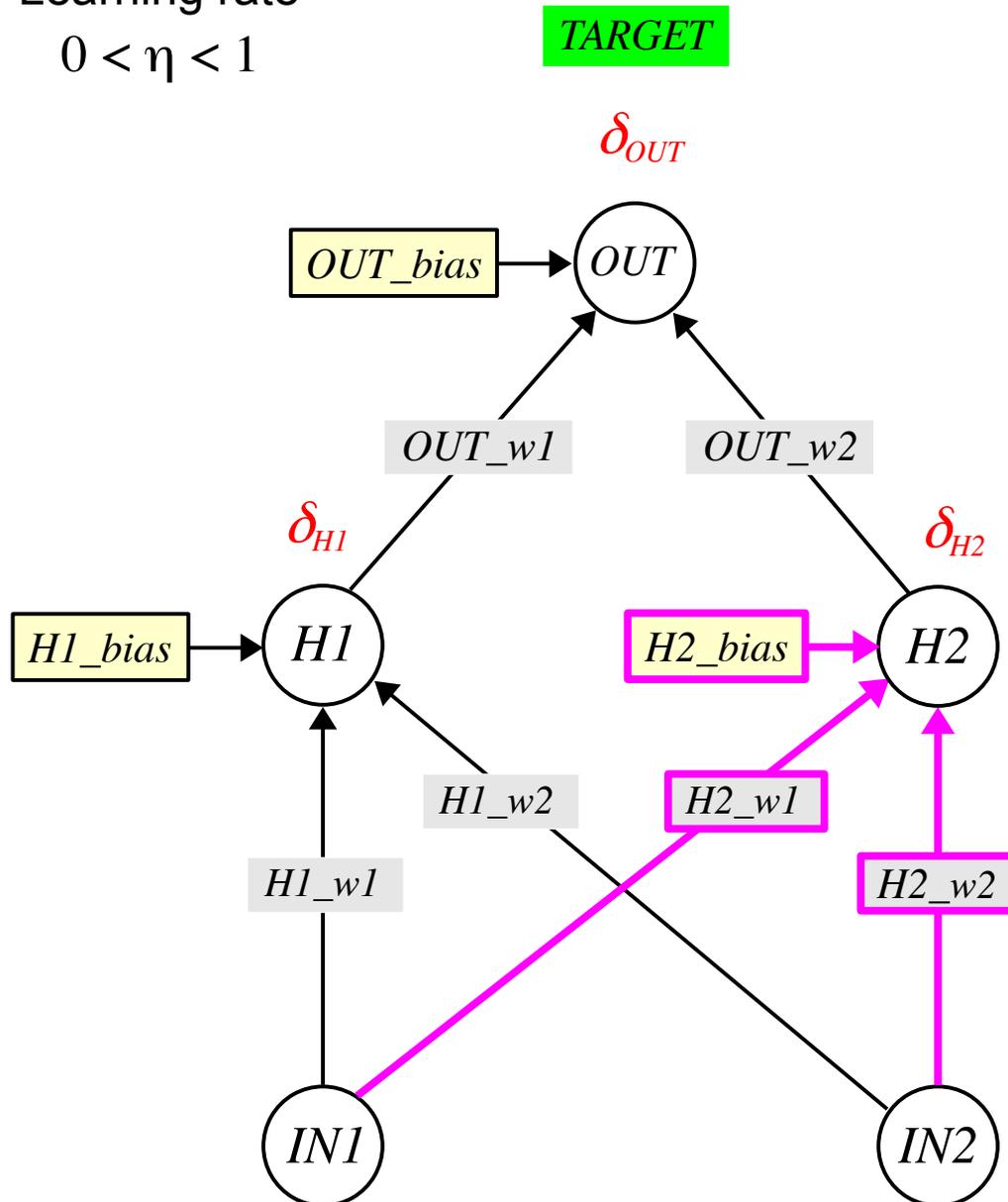
$$\Delta H1_w1 = -\eta \times \delta_{H1} \times IN1$$

$$\Delta H1_w2 = -\eta \times \delta_{H1} \times IN2$$

$$\Delta H1_bias = -\eta \times \delta_{H1}$$

Backpropagation: 2-2-1 Network

Learning rate
 $0 < \eta < 1$



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_w1) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_w2) \times H2 \times (1 - H2)$$

$$\Delta OUT_w1 = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_w2 = -\eta \times \delta_{OUT} \times H2$$

$$\Delta OUT_bias = -\eta \times \delta_{OUT}$$

$$\Delta H1_w1 = -\eta \times \delta_{H1} \times IN1$$

$$\Delta H1_w2 = -\eta \times \delta_{H1} \times IN2$$

$$\Delta H1_bias = -\eta \times \delta_{H1}$$

$$\Delta H2_w1 = -\eta \times \delta_{H2} \times IN1$$

$$\Delta H2_w2 = -\eta \times \delta_{H2} \times IN2$$

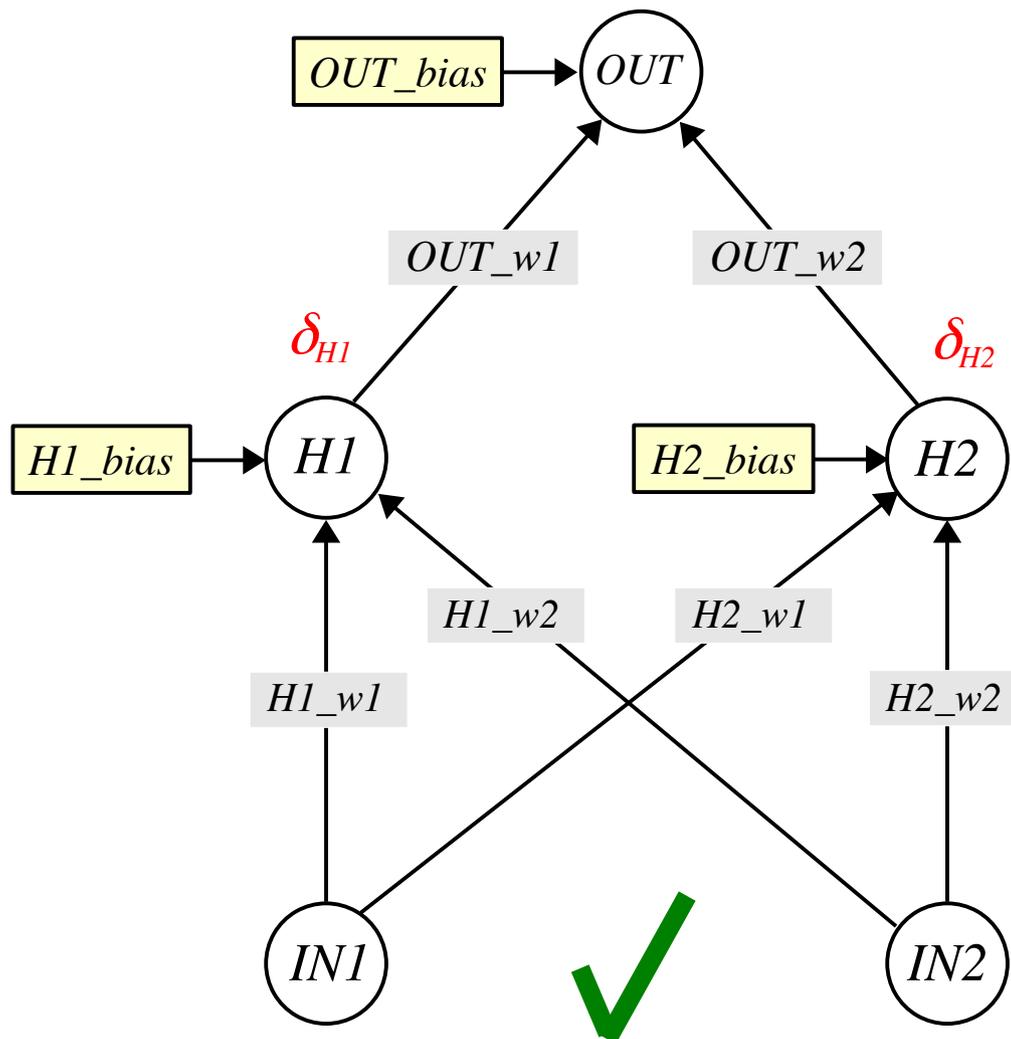
$$\Delta H2_bias = -\eta \times \delta_{H2}$$

Backpropagation: 2-2-1 Network

Learning rate
 $0 < \eta < 1$

TARGET

δ_{OUT}



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_{w1}) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_{w2}) \times H2 \times (1 - H2)$$

$$\Delta OUT_{w1} = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_{w2} = -\eta \times \delta_{OUT} \times H2$$

$$\Delta OUT_{bias} = -\eta \times \delta_{OUT}$$

$$\Delta H1_{w1} = -\eta \times \delta_{H1} \times IN1$$

$$\Delta H1_{w2} = -\eta \times \delta_{H1} \times IN2$$

$$\Delta H1_{bias} = -\eta \times \delta_{H1}$$

$$\Delta H2_{w1} = -\eta \times \delta_{H2} \times IN1$$

$$\Delta H2_{w2} = -\eta \times \delta_{H2} \times IN2$$

$$\Delta H2_{bias} = -\eta \times \delta_{H2}$$

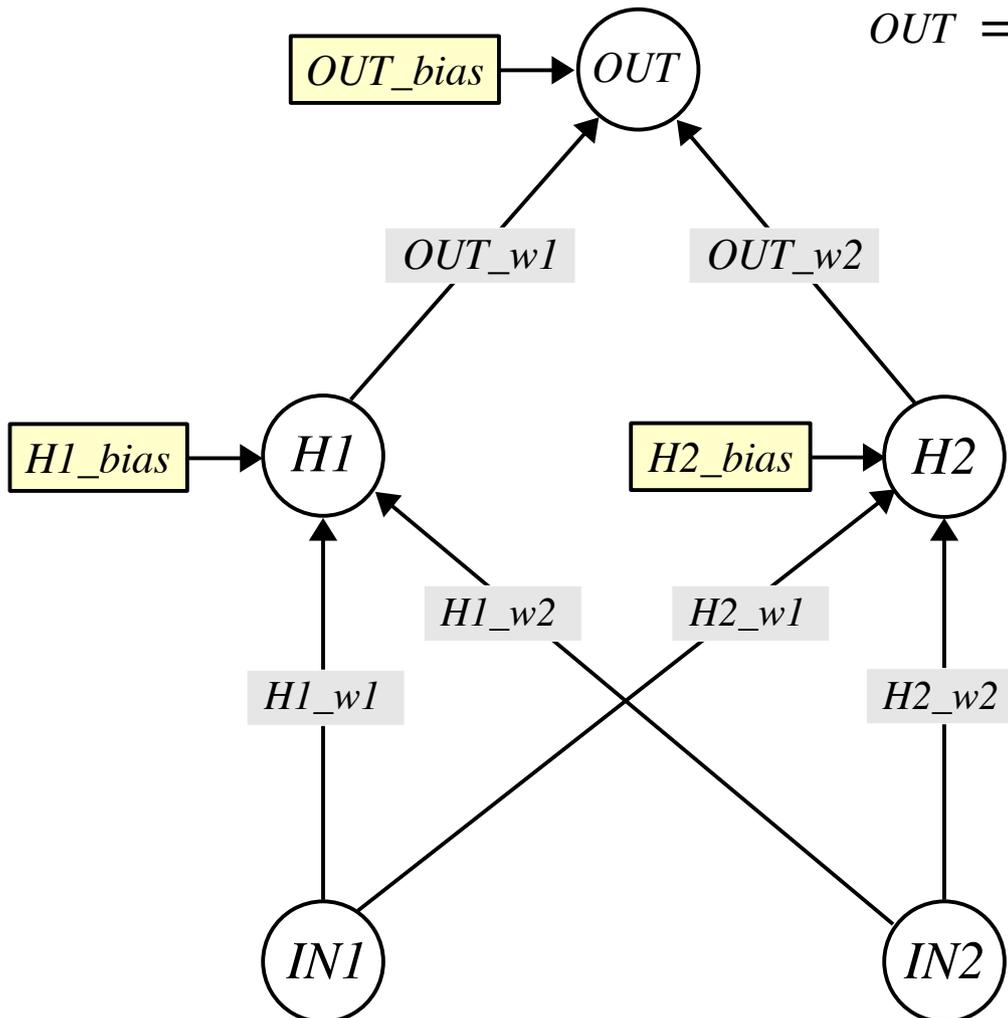
Summary: 2-2-1 Network – Forward Pass

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

$$H1 = \sigma(IN1 \times H1_w1 + IN2 \times H1_w2 + H1_bias)$$

$$H2 = \sigma(IN1 \times H2_w1 + IN2 \times H2_w2 + H2_bias)$$

$$OUT = \sigma(H1 \times OUT_w1 + H2 \times OUT_w2 + OUT_bias)$$

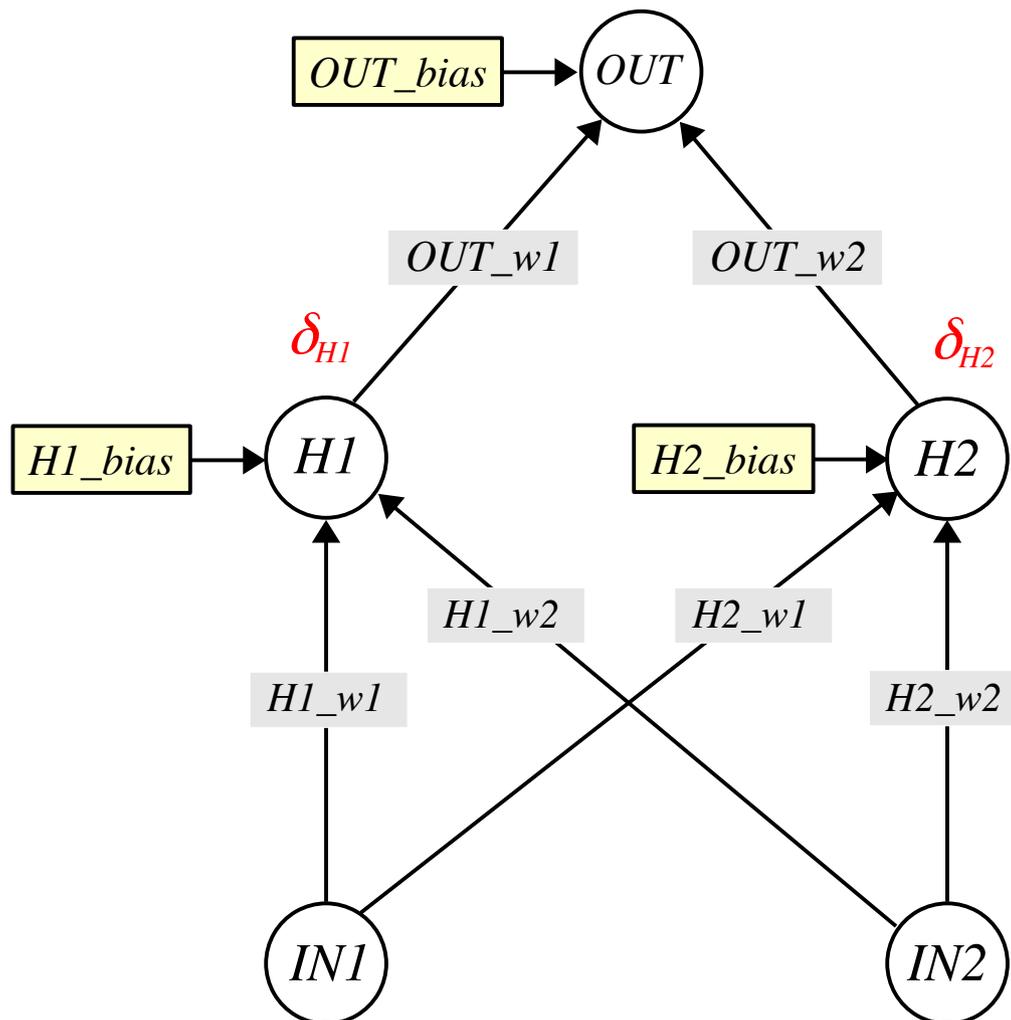


Summary: 2-2-1 Network – Backward Pass

Learning rate
 $0 < \eta < 1$

TARGET

δ_{OUT}



$$\delta_{OUT} = (OUT - TARGET) \times OUT \times (1 - OUT)$$

$$\delta_{H1} = (\delta_{OUT} \times OUT_{w1}) \times H1 \times (1 - H1)$$

$$\delta_{H2} = (\delta_{OUT} \times OUT_{w2}) \times H2 \times (1 - H2)$$

$$\Delta OUT_{w1} = -\eta \times \delta_{OUT} \times H1$$

$$\Delta OUT_{w2} = -\eta \times \delta_{OUT} \times H2$$

$$\Delta OUT_{bias} = -\eta \times \delta_{OUT}$$

$$\Delta H1_{w1} = -\eta \times \delta_{H1} \times IN1$$

$$\Delta H1_{w2} = -\eta \times \delta_{H1} \times IN2$$

$$\Delta H1_{bias} = -\eta \times \delta_{H1}$$

$$\Delta H2_{w1} = -\eta \times \delta_{H2} \times IN1$$

$$\Delta H2_{w2} = -\eta \times \delta_{H2} \times IN2$$

$$\Delta H2_{bias} = -\eta \times \delta_{H2}$$